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DEVELOPMENT OF ELEMENTS OF A HIGH Tc SUPERCONDUCTING CABLE

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PROGRAM SUMMARY

The redirected program is aimed at the development of long lengths of silver-clad BSCCO. BSCCO-2223 is the material of choice with 20K the operating temperature goal. Such a tape conductor ultimately could be used in a coil for a magnet, motor or generator.

The program is designed to tackle several key problems with parallel tasks. A large variety of BSCCO powders will be prepared. Silver tubes packed with superconductor powder will be cold deformed to form tape conductors. Alternate methods of making silver-encapsulated superconducting tape will be explored. Variations in the powders and processing parameters will be used to optimize the tape Jc.

Good progress has been made on several fronts:

(1) It has been convincingly demonstrated that the highest Jc tapes are prepared from powder which is not fully reacted to BSCCO-2223.

(2) The superiority of pressing over rolling for the final deformation of the tapes has been proven and tentatively explained.

(3) Equipment is now available to measure currents up to 240A at 20K in fields as high as 9T.

(4) A low Jc degradation of bent tapes will allow coiled lengths to be processed.

PROGRESS

TASK 1 -- POWDER PRODUCTION

The goal of this task is the production of reproducible, large powder batches of BSCCO to be used in the tape development effort.

A major advance this quarter was the verification that fully reacted 2223 powders are not the desired starting material. The highest Jc values in the final processed tape are obtained when the reaction to form 2223 occurs during the final heat-treatment. More details on the need for non-reacted powders are discussed under task 5. We are continuing to explore the effect of varying the cation ratios in the powder mixes. In addition, starting mixes with different phase assemblages are under consideration. The ultimate goal is to define the initial powder which yields the highest Jc in the tape.

TASK 2 -- TAPE FABRICATION USING POWDER-IN TUBE

Deformation of BSCCO-filled silver tubes is done by sequential swaging, drawing, and rolling. The tapes are then subjected to final deformation and heat-treatment cycles under task 5 to optimize properties, especially Jc. The aim of this task is to provide tapes for the Jc optimization studies.

A process for fabricating tapes as thin as 0.1mm is in-hand. 110mm long powder columns packed into silver tubes result in 2.7m long tapes 0.25mm thick and about 3mm wide. We can make tapes with high volume fractions of superconductor and as thin as 0.1mm. **14 meter long 0.25 mm thick tapes have been made using commercially available 0.5m silver tubes.** Longer lengths could be made depending on the availability of longer starting tubes. A large number of different powders have been PIT processed into tape form. We continue to explore the effect of deformation processing variables on the superconductor configuration in the final tape.

TASK 3 -- EXTRUDED TAPE FABRICATION

An alternate process for the fabrication of high-Tc conductor Silver-Slad Tape (SCT) is under study. The first step is to extrude a thin tape containing BSCCO and organic binder. A heat-treatment in an oxidizing atmosphere is used to remove the organics from the composite tape.

We have demonstrated the ability to extrude 0.4mm thick BSCCO tapes using a GE-developed binder. The screw-driven extruder can make tape continuously of any desired length. The die is now being modified to allow vertical extrusion for the production of a more uniform product.

TASK 4 -- SILVER FOIL WELDING

The second step in the new Silver Clad Tape (SCT) process is the sealing of the edge of the silver foil wrapped around the BSCCO tape. This was to be done using pressure welding.

An improvement in the process now seems feasible. We have shown that if a lap joint of the silver foil is simply pressed together, the silver cladding diffusion bonds during the superconductor heat treatment process. The bond survives subsequent deformation (rolling or pressing) of the tape. The SCT process now under consideration involves wrapping silver foil around the tape (after binder removal) and then processing in a similar manner to PIT tape.

TASK 5 -- SUPERCONDUCTOR OPTIMIZATION

This task studies the optimization of the Jc of silver-clad BSCCO tapes. Transport Jc measured at 77K with no applied field continues to be used as a rapid measure of sample quality. More detailed measurements as a function of temperature and field will be done on selected samples. Short samples and small coils can be tested at 4.2K with currents up to 1000A and fields up to 10T. In this quarter, we have upgraded our capability to measure transport Jc at the intermediate temperatures of interest to this program. **A variable temperature apparatus capable of measuring up to 240A at fields up to 9T is now available.**

This task will of necessity involve many iterations to determine the best set of processing parameters. This involves choice of the correct powder as well as the optimum deformation and heat treatment cycles. Information from results of a parallel GE CRD contract with ORNL showed that high Jc values in PIT tapes could be obtained starting with 2212 powders and reacting to 2223 after fabrication of the tape configuration. This indicated fully reacted 2223 powder may not be desired. Two PIT tapes were made with the same power composition but with one fully reacted to 2223 and the second only partially reacted. **Tapes made from the partially reacted powder consistently gave higher Jc values. The reason for this is now under study, but it seems likely that more grain growth and better intergrain connectivity is obtained if "reaction sintering" is done as compared to sintering a fully reacted product.**

The choice of deformation modes used during the final processing of tapes has been shown to be crucial. **We have shown that pressing is much superior to rolling to obtain high Jc values.** Figure 1 shows a comparison of tapes of partially and fully reacted powders where the final processing sequence involved either rolling or pressing. We believe the advantage of pressing is the densification of the superconductor portion of the tape. During rolling of the silver-clad composite the superconductor sees a longitudinal tensile stress from the silver deformation. This additional tensile stress prevents the rolled tape from densifying to the same extent as the pressed tape. We have built a special pressing jig to allow semicontinuous pressing of long tapes.

TASK 6 -- LONG LENGTH AND SINGLE COIL PROPERTIES

The properties of long lengths will be studied using coiled tapes. Uniformity along the tape is particularly important.

A necessary condition for the processing of long lengths is the ability to coil the tapes so that the heat-treatments can be done in a batch mode. Tapes with thicknesses as high as 0.25mm total thickness must be bent around radii small enough to allow coils to be placed in small furnaces. In addition the final tapes must have reasonable bend tolerances to allow small coils to be made. Figure 2 shows the effect on Jc of bending a tape around a circular form and then testing in the curved configuration. **It can be seen that our**

tapes can be coiled to diameters as low as 75mm with minimal degradation in properties.

TALKS AND PAPERS

KW Lay, "C-Axis Texturing in High Tc Superconductors", Talk given at DARPA Workshop on HTS Bulk Technology, Santa Fe, NM, 1/31/91

JE Tkaczyk,, RH Arendt, PJ Bednarczyk, MF Garbauskas, KW Lay, "Transport Critical Current Measurements of Bi-Sr-Ca-Cu-O High Temperature Superconductors", Talk given at American Physical Society Spring Meeting, Cincinnati, OH, March, 19910

GOALS FOR NEXT QUARTER

Clarify the relationship between the initial powder phase assemblage and the tape Jc.

Continue fabrication of PIT tape

Prepare silver-wrapped conductor tapes from extruded powder.

Continue study of factors influencing Jc of PIT and SCT tapes

Study of Jc of longer tapes

FINANCIAL STATUS

All values are cost plus fixed fee total costs.

TOTAL FUNDING REQUIRED FOR EFFORT $2,424,530
01Sept88 through 31Aug91 (36 months)

CURRENT AUTHORIZATION 1,668,000
01Sept88 through 31Jan91 (29 months)

FUNDING EXPENDED TO-DATE 1,650,800
01Sept88 through 31Mar91 (31 months)

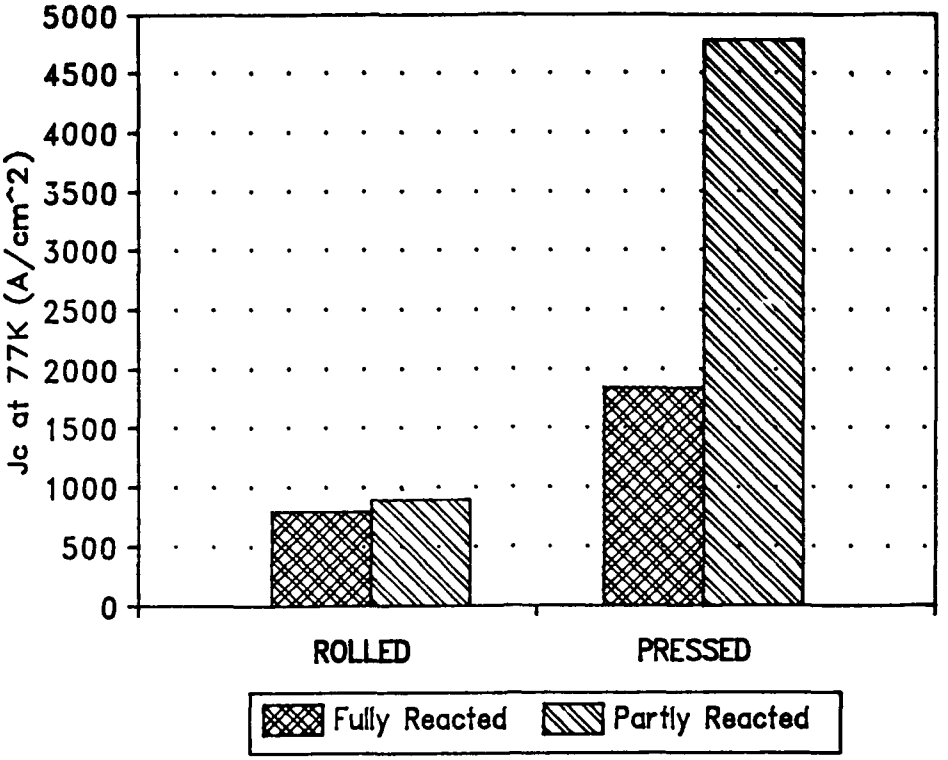

Figure 1 Critical current density of BSCCO-Ag tapes at zero applied field. Demonstrates the effect of initial powder 2223 content and final deformation method on Jc. Tapes were swaged, drawn, and rolled to 0.25mm thickness and heat treated 48hr at 830^{o}C in air. They were then either rolled to 0.125mm or pressed followed by a second identical heat treatment

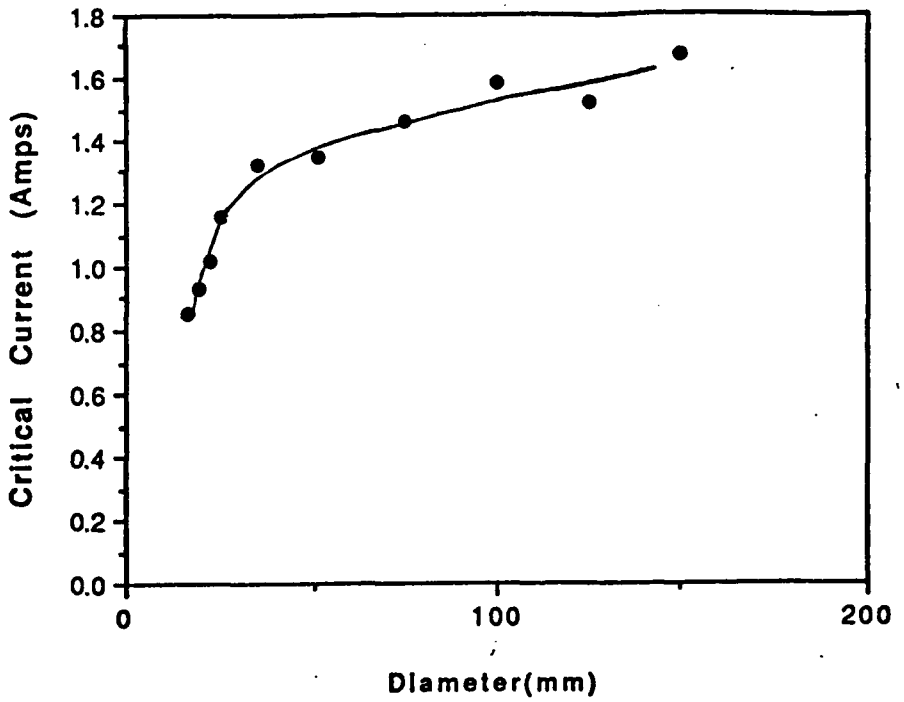

Figure 2 Critical current of 0.19mm BSCCO-Ag tapes at 77K and zero applied field as a function of bending deformation. Superconductor thickness about 0.1mm. Tapes were manufactured flat, bent to indicated diameter and measured as-bent.